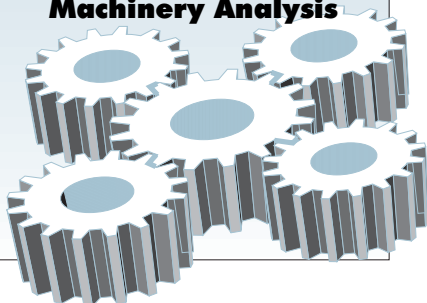


THE BETA BULLETIN



Machinery Analysis

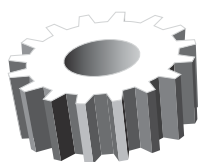


IN VOLUME 7 #3

Pressure Drop Is a Vital Part of the Equation 1

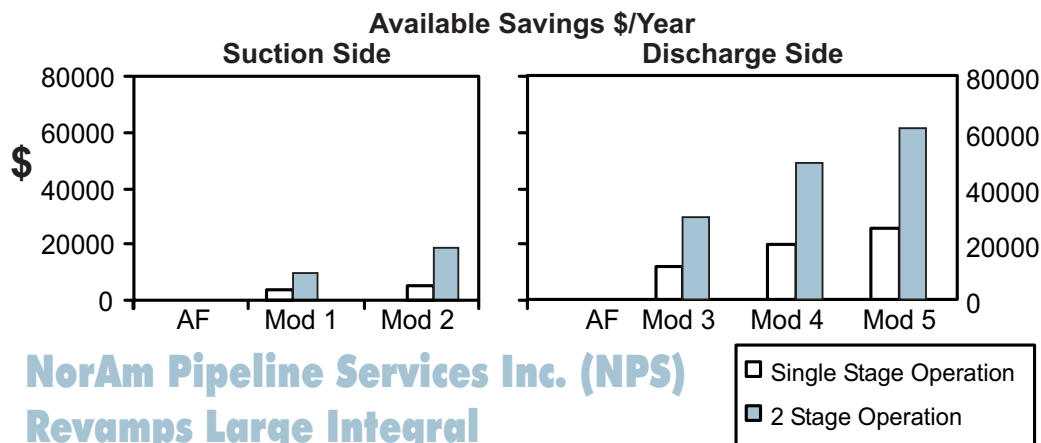
Compressor Performance Testing Saves Dollars 2

Free Seminar Program 4



\$57,000 Saving Per Year

Acoustical Analysis at NorAm Pipeline Services Inc. Reverses Excess Pressure Drop Caused by Compressor Revamp



NorAm Pipeline Services Inc. (NPS) Revamps Large Integral

NPS planned to revamp an existing 2 stage 4000 HP 310 RPM integral. Both its vibration levels AND economic performance had been satisfactory. Steve Walker, Project Manager at NPS's Shreveport site, decided to significantly increase the flow, and to restage the compressor so that it could operate either as a single stage or a 2 stage unit. The revamped unit compressed about 205 MMSCFD in single stage mode through 7 cylinders. In two stage mode, it compressed about the same amount through 4 cylinders. Most of the gas was diverted elsewhere, and the 3 cylinders on second stage compressed only about 28 MM. Our challenge was to see what effect these changes would have and recommend improvements if necessary.

The acoustical model indicated that vibration levels in the revamped compressor would still not be a problem, but that pressure drop (excessive horsepower requirements, and therefore excessive fuel demand) would have a huge impact on operations costs, particularly in the two stage mode.

In the graphs shown here, AF (AS FOUND) is taken as the base, and represents the revamped but unmodified state. Our calculations

indicated that pressure drops were at **least twice** as high as API allowable and in some cases **over seven times** allowable. Dollar figures are calculated on the basis of a fuel cost of \$200 per HP per year.

Two modifications were offered for the suction side (Mod 1 and 2) and three for the discharge side (Mods 4, 5 & 6), all with acceptable pulsation levels. The dollar savings per year are shown in the graph. Mods 2 (best for suction side) and 5 (best for discharge side) both involved changing a 15 foot spool piece and modifying the bottle. Modification cost was in the range of \$40,000 altogether, and the analysis of this complex system cost \$32,500.

If we assume that the compressor would operate single staged for half the year, and two staged for the other half, cost comparisons are as follows:

$$\text{Suction Side: } \frac{1}{2} \$7800 + \frac{1}{2} 19800 = \$13,800 \text{ per year.}$$

$$\text{Discharge Side } \frac{1}{2} \$25000 + \frac{1}{2} \$62000 = \$43,500 \text{ /yr.}$$

NPS chose to modify both sides at once. The overall return *in one year* is approximately \$57,000 and the payback period just over 15 months. Steve Walker says "everything is working just fine".

www.betamachinery.com
Try it out.

Compressor Performance Testing - A Service of Beta Machinery Analysis

Wasting 1% of fuel per year, on a 10,000 HP unit, can cost \$16,000.

Wasting 1% of capacity per year, on a 100 MMSCFD unit, can cost \$167,000.

Accurate performance equations and curves will help you realize these savings.

Payback period in these cases would be weeks or months.

Capacity Optimization

- improved utilization of capacity
- better decisions on capital investments (ensure full utilization of existing machinery before adding new)
- more accurate forecast of capacity (improves marketing)

Efficiency Improvement

- increased operational efficiency (run the most efficient units in the most efficient manner)
- better information on which to configure the pipeline
- provision of accurate baselines to use for later detection of deviations
- ability to maintain safe operating ranges

Maintenance Optimization

- reduced machinery abuse (reduce instances of overload and the resulting lost availability and increased maintenance)

What Is It?

Performance testing of compressors, either centrifugal or reciprocating, is a special test sequence from which baseline performance characteristics are generated. Results can be presented in the form of empirical equations and/or performance curves. The attributes generated include power, throughput and efficiency all expressed as functions of suction pressure, discharge pressure, suction temperature, speed and gas properties.

Additionally, results show operating limits such as rod load limit for reciprocating compressors and surge limit for centrifugal compressors.

Why Do It?

Existing performance data is often less accurate than it could be; errors are often as great as 10-20%. This occurs because of the use of theoretical curves or generic curves for a type of compressor. Even where test based curves are provided, they generally

do not reflect the operating characteristics as installed *in this location*. In addition, there have often been changes made over the years without new performance baselines being generated. As a result, the unit can be overloaded or the capacity can be underutilized and/or safe operating ranges can be exceeded. For example, surge limits in centrifugal compressors tend to be conservative, resulting in unnecessary amounts of recycle and loss of efficiency.

Cost of 1% Wasted Fuel

The economic impact of accurate performance data can be very large. To illustrate, suppose we have a centrifugal compressor operating such that, on average, we recycle 1% more flow than necessary. Let us assume this is a 10,000 HP unit with a BSFC of 10,000 BTU/HP-hr. Then since we are wasting 1% of the power and, therefore, of the fuel, we can calculate the cost of the wasted fuel. Suppose fuel costs

\$2 per MCF. If the fuel has a lower heating value of 1000 BTU/R³, then the cost of wasted fuel, per year is:

$$\text{Excess cost} = (10000 * 10000 / 1000) * 1 / 1000 * \$2 * 8000 * 0.01 = \mathbf{\$16,000 \text{ per year.}}$$

Cost of 1% Wasted Capacity
Suppose we have a unit capable of moving 100 MMSCFD, but which is operating 1% below its capability. If the value of compressing gas is \$.50/MMSCF (an arbitrary but representative value), then the opportunity cost would be:

$$\text{Opportunity cost} = (100 / 24) * 1000 * 0.01 * 0.50 * 8000 = \mathbf{\$167,000 \text{ per year.}}$$

Significant excess costs due to unit overloading also arise from loss of availability and excess maintenance costs.

Compressor Performance Testing Procedure

The starting point for compressor performance tests is a unit in good, normal mechanical condition. Provision must exist or be made to measure suction and discharge pressures to within about 1 psi, depending on actual pressures involved. Suction and discharge temperatures must be measured accurately, typically to within 0.1 deg F. Provision must also be made to operate the unit over a range of typical operating conditions.

Gas composition must be determined, either from gas samples or from an on line gas chromatograph.

Each test run involves setting the unit up in the selected operating condition and ensuring stability has been achieved. Then the required data is collected. As the test runs proceed, collected data is analyzed and evaluated for validity.

Reciprocating Compressor Performance Testing

During each test run, indicated horsepower is determined with a calibrated and well set up compressor analyzer, based on pressure-volume curves from each cylinder end. The test runs cover the expected ranges of compression ratio and load step. Usually tests at six to ten operating conditions are sufficient.

Centrifugal Compressor Performance Testing

For centrifugal compressor performance testing, measurement of flow is a requirement. One additional measurement is vibration, used to detect the onset of surge. The test procedure again involves operating the unit over a range of normal, stable operating conditions at various flows and compression ratios.

Results

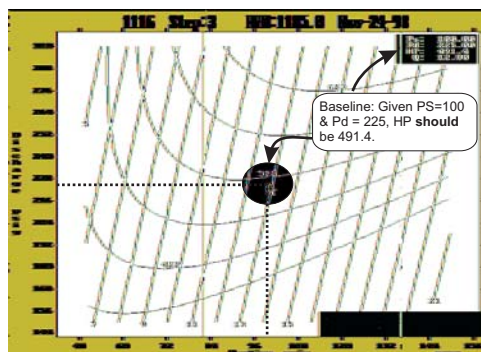
After sufficient test runs, empirical performance equations are generated using regression analysis. Part of the process is an evaluation of the quality of the results, represented by correlation coefficients. The testing process is completed via several independent test runs at different operating points to verify the equations.

The resulting precise empirical performance equations can be used

- to generate accurate performance curves
- to program accurate control algorithms in a control system
- by gas control for more accurate modeling and more efficient operation
- to provide system planning with more accurate information for marketing and for capital expenditures.

Beta can generate accurate equations, *and* can help you make the best use of them.

Beta's compressor performance testing service has been developed by and is directed by leading experts in the field.



Today's Reading
(from analyzer)

Actual	530
Baseline	491
Deviation	39
% Dev	8

Empirical performance tests provide the best base lines for ongoing performance monitoring. Here, the actual HP exceeds the baseline by over 8% for the current operating point. This indicates performance and/or mechanical degradation requiring investigation, and likely, correction.

Free Seminar Program

Coming Soon--Turbines
Are you interested?

Recip Pulsation
and Vibration

Beyond Predictive
Maintenance

Torsional
Analysis

Still offered. Still beneficial.
See insert with this Beta Bulletin,
or call for details.
On site courses are also available.

New Seminar: Balancing Compressor Design with Risk

Objectives of the Seminar

Understand "exposure" and its sources.

Determine level of need for design analysis (increases and decreases in "exposure" based on unit, operating conditions, service and location).

Identify appropriate levels of analysis for various levels of "risk".

Understand API's approaches to compressor design.

Who Should Attend

This seminar is useful for anyone involved in the design and construction of new or revamped compressor installations.

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www.betamachinery.com

Check out the bulletin board.

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